POLITEKNIK MALAYSIA
KUCHING SARAWAK

RENEWABLE ENERGY IN PRACTICE : INTERACTIVE WORKSHEETS

1st Edition

AZARINA AZMAN

SITI SUNAIDAH SUKMA SUBRI

Authors

AZARINA BINTI AZMAN
SITI SUNAIDAH SUKMA BINTI SUBRI

POLITEKNIK KUCHING SARAWAK
MINISTRY OF HIGHER EDUCATION
KM22, JALAN MATANG,
93050 KUCHING, SARAWAK.

PHONE NO. : (082) 845596/7/8
FAX NO. : (082) 845023
E-MAIL : POLIKU.INFO@POLIKU.EDU.MY
WEBSITE : HTTP://WWW.POLIKU.EDU.MY/

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HAK CIPTA TERPELIHARA DAN PENAFIAN

ABOUT AUTHOR

AZARINA AZMAN

Academic Qualification :

- Master of Engineering (Electronic Engineering), UNIMAS, (2020).
- Bachelor Degree in Electronic and Telecommunication Engineering, UNIMAS (2006).

Teaching Experience : 17 years

SITI SUNAIDAH SUKMA SUBRI

Academic Qualification :

- Master of Engineering (Electrical-Power), UTM (2015)
- Bachelor of Electrical Engineering With Hons. (Power Electronic & Drive), UTEM, (2013)

Teaching Experience : 5 years

PREFACE

RENEWABLE ENERGY IN PRACTICE : INTERACTIVE WORKSHEETS

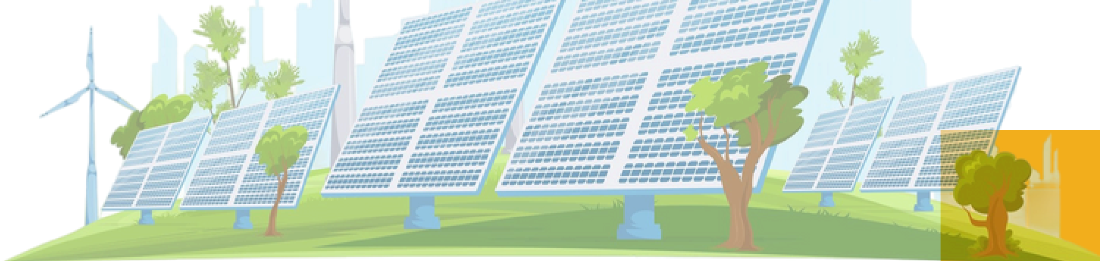
BY
AZARINA AZMAN
SITI SUNAIDAH SUKMA SUBRI

Renewable energy is one of the efforts that leads to a sustainable and environmentally friendly future. The move from long-standing fossil fuels to renewables is not only a scientific and engineering challenge, but it will also result in significant educational endeavor. This book, **"Renewable Energy in Practice: Interactive Worksheets"** is written with the objective of reducing this gap between theoretical knowledge and practical application. It is aimed to provide students with the knowledge and skills related to renewable energy.

This book includes six hand-on worksheets designed to provide practical experience in four key areas of renewable energy: **solar energy, wind energy, hydro energy** and **fuel cells energy**. Each section contains interactive worksheets that are structured to reinforce learning through active engagement. This book also comes with interactive exercise in games form, which help students deepen their understanding based on the practical experience. Engaging in these exercises will enable students to develop a more profound comprehension of the functioning of these technologies, as well as their benefits, constraints, and their significance in shaping the global energy environment.

"Renewable Energy in Practice: Interactive Worksheets" is more than just a textbook; it is a tool for discovery and innovation. By engaging with the material in a hands-on manner, students will not only learn about renewable energy technologies but also develop the skills needed to contribute to a sustainable future.

Let's embark on this educational adventure together and contribute to a brighter, cleaner, and more sustainable world.



ABSTRACT

RENEWABLE ENERGY IN PRACTICE : INTERACTIVE WORKSHEETS

BY
AZARINA AZMAN
SITI SUNAIDAH SUKMA SUBRI

"**Renewable Energy in Practice: Interactive Worksheets**" is a pedagogical resource developed to enhance the understanding and application of renewable energy concepts through interactive learning. This book provides a series of worksheets covering various renewable energy technologies, including solar, wind, hydro, and fuel cell energy. Each worksheet is designed to facilitate hands-on learning, encouraging students to engage with the material actively and apply theoretical knowledge in practical contexts.

The interactive worksheets included in this book offer a range of activities, from problem-solving exercises to experimental setups, enabling students to explore the principles and operations of renewable energy systems. The worksheets encourage readers to analyze data, solve problems, and conduct experiments, making the learning process dynamic and interactive. This resource is ideal for use in educational settings, including classrooms and laboratories, and is suitable for students at different levels of their education in renewable energy and related fields. By integrating these worksheets into their curriculum, educators can foster a deeper understanding of renewable energy technologies and their applications, preparing students to contribute effectively to the transition towards sustainable energy futures.

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Practical Work 1

PERFORMANCE ANALYSIS ON SINGLE AND SERIES CONNECTION OF SOLAR CELLS

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PRACTICAL WORK 1 : PERFORMANCE ANALYSIS ON SINGLE AND SERIES CONNECTION OF SOLAR CELLS

CLO 2	Measure input and output parameters of renewable energy system using appropriate tools and equipment. (P4)	**PLO 5**	**DP1, DP3, DP4**
CLO 3	Demonstrate understanding of environmental & sustainability practices in renewable energy field through a given task session. (A3)	**PLO 7**	

A. OBJECTIVES

i. Investigate the shading effect on the solar module in single and series connection.
ii. Interpret the current voltage (I-V) performance of the solar module in single and series connection with shading and tilt angle effect.

B. LEARNING OUTCOME

Conduct performance measurements (voltage, current) of a single and series solar cell connection under various lighting conditions.

C. THEORY

Solar cells, also known as photovoltaic (PV) cells, are semiconductor devices that convert sunlight directly into electricity. The performance of these cells can be significantly influenced by their configuration, particularly whether they are connected individually (single) or in series. Understanding the performance characteristics of both configurations is crucial for optimizing the efficiency and reliability of solar power systems.

A single solar cell operates as an independent unit, converting light into electrical energy. The performance of a single cell can be characterized by parameters such as the open-circuit voltage (Voc), short-circuit current (Isc), fill factor (FF), and efficiency (η).

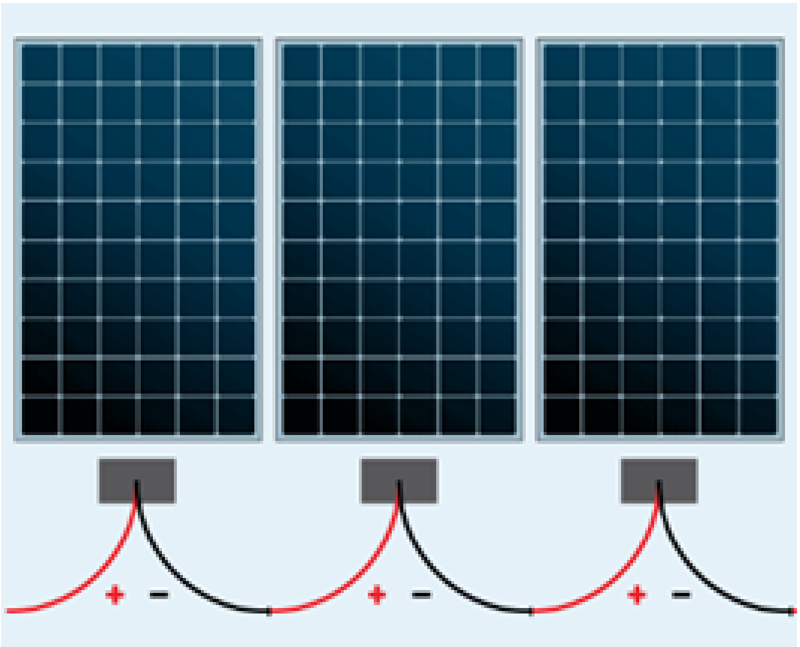
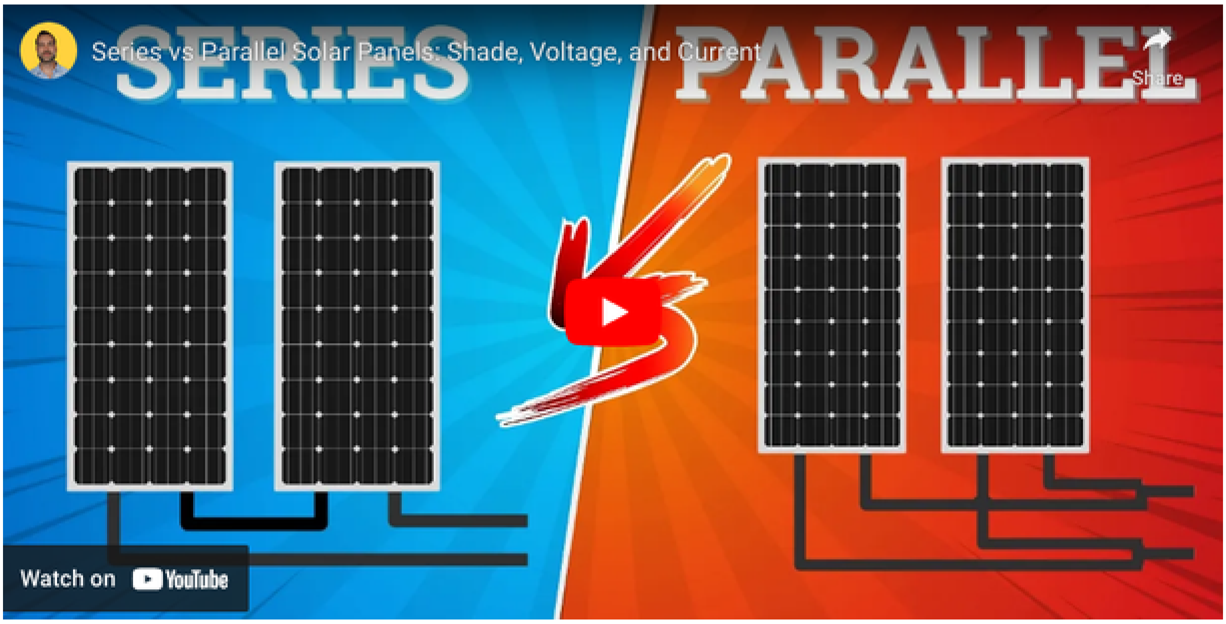


Figure 1.1 : Series Connection of solar panel [1]

A series connection can be designed by connecting the positive terminal of one panel to the negative terminal of another panel as shown in Figure 1.1. This connection resulting the voltage of the panels adds together but the current remains the same as current travel along only one path. Therefore, all the current in the circuit must flow through all the loads. A series circuit is a continuous, closed loop - breaking the circuit at any point stops the entire series from operating.

The purpose of this experiment is to measure the voltage and current by connecting two solar cells in single and series connection with shading effect. Students will also be able to interpret the gathered measured voltage and current in characteristic curve of the system. Figure 1.2 shows comparison between series and parallel connection of solar panel.



Source : YouTube Cleversolarpower

Figure 1.2 : Series vs Parallel Solar Panels: Shade, Voltage, and Current

D. MATERIAL / TOOLS

- 2 unit of 6V solar cells (11cm x 6cm)
- Multimeter
- Sufficient electrical leads with alligator clip
- Thick paper

E. SAFETY PRECAUTION

- Wear suitable PPE where required.
- Identify location of Fire Exit, Fire Extinguisher, First Aid Kit box and HIRARC sheets.
- Avoid unsafe activities during practical work.
- Carefully follow the lecturers' instructions to avoid personal injury and damage to the equipment.
- Check the hand tools and equipment in good working condition.
- Verify electrical power supply connection before powering up. Seek advice from lecturer when necessary or if the practical work procedures require you to do so.
- Never remove any component when the power is on.
- Read direction and procedure of the experiments very carefully.
- Always take precautions in handling measurements of voltage and current.

F. PROCEDURES

Part 1 : Shading Effect on Single Connection of Solar Cell

1. Attach the wire or two electrical leads with an alligator clip to a solar cell and connect red probe of the multimeter with the positive terminal of the solar cell while the black probe of the multimeter will connect to the negative terminal of the solar cell as Figure 1.3.
2. Expose the solar cell direct to the sunlight as shown in Figure 1.3.
3. Record the readings of voltage and current in solar cells in Table 1.1.
4. Keeping the sunlight constant, shade $1/2$ of the solar cell with the piece of carboard or thick paper.
5. Record the readings of voltage and current in Table 1.1.
6. Repeat steps 4-5 with shading the entire of solar cell.

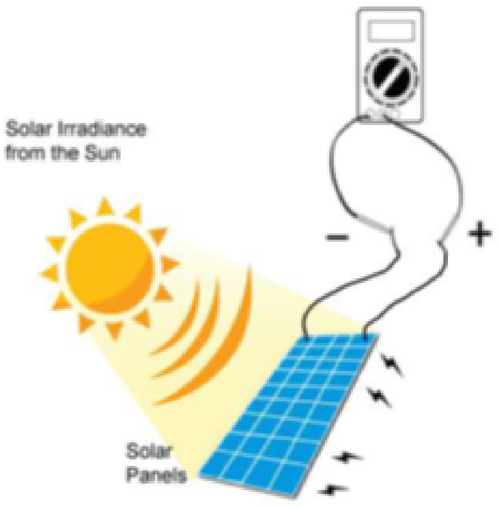


Figure 1.3 : Solar panel diagram exposed to sun / light source. [1]

Part 2 : Effect of Shading on Series Connection Solar Cell

1. Take 2 units of 6V solar cells with a size of 11cm x 6cm.
2. Attach the wire or two electrical leads with an alligator clip to a solar cell as Figure 1.4.
3. Joined the –ve terminal of solar cell A with +ve terminal of solar cell B.
4. Connect the +ve terminal of solar cell A to red lead of multimeter. Similarly, connect the –ve terminal of solar cell B to the black lead of the multimeter.

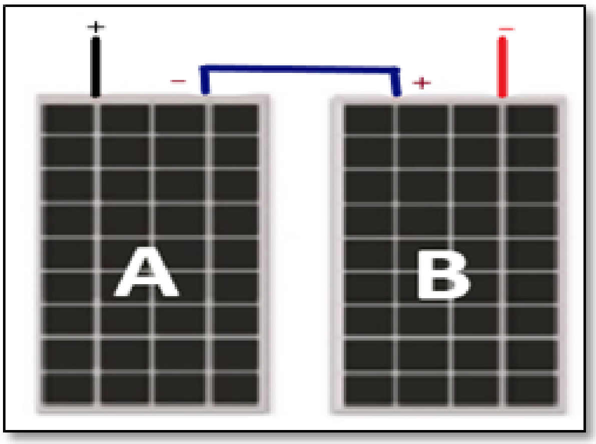


Figure 1.4 : Series connection of solar cell

5. Use the sun or shine a light source on the solar cell as in Figure 1.3.
6. Record the current and voltage reading for unshaded solar cells in Table 1.2.
7. Keeping the sunlight constant (or the light source at constant distance), shade ½ of one solar cell with a piece of cardboard or thick paper.

8. Record the voltage and current of the solar cell readings in Table 1.2.
9. Repeat the step 7 with the shading of the entire solar cell.
10. Record the voltage and current of the solar cell readings in Table 1.2.

G. RESULT

Table 1.1 : Performance of single solar cell under shading effect (11cm x 6cm). (DP1, DP3, DP4)

SHADED AREA CONDITION	SINGLE CONNECTION	
	CURRENT (mA)	VOLTAGE (V)
No Shade		
Half Covered		
Entirely Covered		

Table 1.2 : Performance of series solar cell under shading effect (11cm x 6cm). (DP1, DP3, DP4)

SHADED AREA CONDITION	SERIES CONNECTION	
	CURRENT (mA)	VOLTAGE (V)
No Shade		
Half Covered		
Entirely Covered		

Practical Work 2

PERFORMANCE ANALYSIS ON SINGLE AND PARALLEL CONNECTION OF SOLAR CELLS

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PRACTICAL WORK 2 : PERFORMANCE ANALYSIS ON SINGLE AND PARALLEL CONNECTION OF SOLAR CELLS

CLO 2	Measure input and output parameters of renewable energy system using appropriate tools and equipment. (P4)	**PLO 5**	**DP1, DP3, DP4**
CLO 3	Demonstrate understanding of environmental & sustainability practices in renewable energy field through a given task session. (A3)	**PLO 7**	

A. OBJECTIVES

i. Investigate the temperature effect on the solar cell in single connection.
ii. Investigate the shading effect on the solar cell in parallel connection.
iii. Interpret the current voltage (I-V) performance on single and parallel connection of the solar cell.

B. LEARNING OUTCOME

Conduct performance measurements (voltage, current) of solar cells in single and in parallel connection under various lighting conditions.

C. THEORY

For Practical Work 2, experiment focusing on parallel connections in order to increase the current capabilities as shown in Figure 2.1 below.

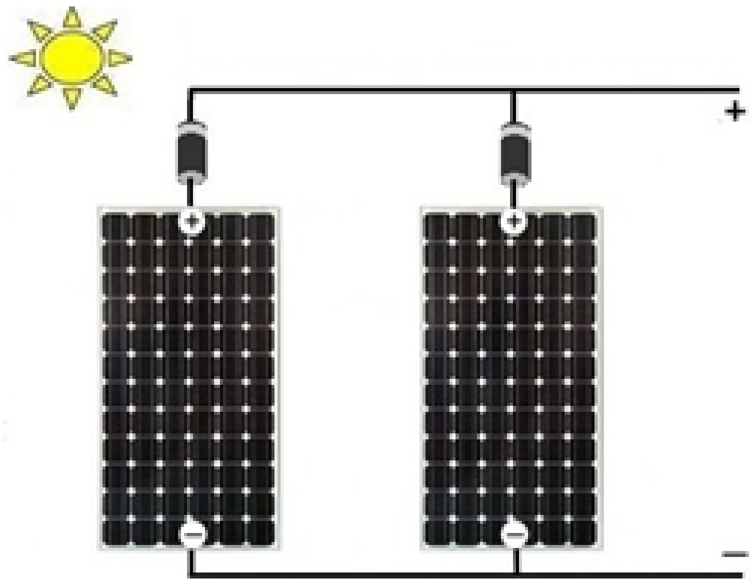
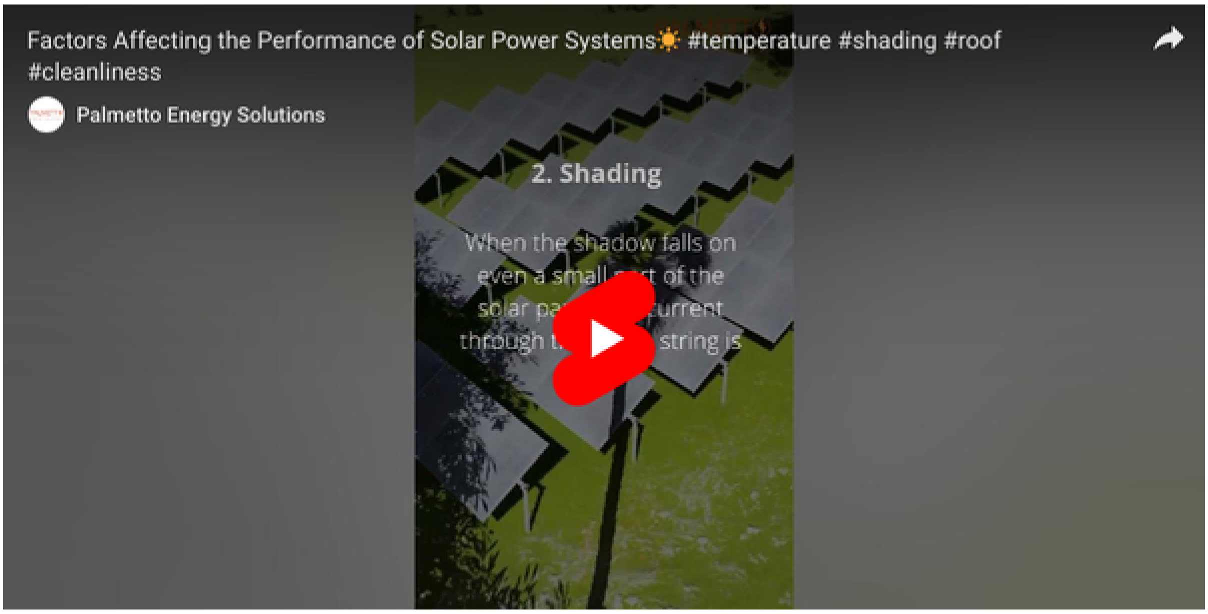


Figure 2.1 : Parallel connection of solar module

With parallel connection, so two identical panels will produce double the current as compared to just one single panel. But while the currents add up, the panel voltage stays the same. In parallel connection, the positive (+) terminals of all the panels are connected together, and all the negative (-) terminals are connected together. Thus resulting one single positive terminal and one single negative terminal which wired to the regulator and batteries as shown in Figure 2.0. The pros of this connection is the solar cells able operate independently of one another. If one panel are broken down or shaded, the current still continue to move along through the other paths as it has multiple paths.

The purpose of this experiment are measuring the voltage and current for single solar cell connection with temperature effect and combination of two solar cells in parallel connection with shading effect. Student will also be able to interpret and explain the voltage and current in characteristic curve of the system. Figure 2.2 shows factors affecting the performance of solar panel.



Source : YouTube Palmetto Energy Solutions

Figure 2.2 : Factors affecting the performance of solar panel

D. MATERIAL / TOOLS

- 2 unit of 6V solar cells (11cm x 6cm)
- Multimeter
- Sufficient electrical leads with alligator clip
- Thick paper

E. SAFETY PRECAUTION

- Wear suitable PPE where required.
- Identify location of Fire Exit, Fire Extinguisher, First Aid Kit box and HIRARC sheets.
- Avoid unsafe activities during practical work.
- Carefully follow the lecturers' instructions to avoid personal injury and damage to the equipment.
- Check the hand tools and equipment in good working condition.
- Verify electrical power supply connection before powering up. Seek advice from lecturer when necessary or if the practical work procedures require you to do so.
- Never remove any component when the power is on.
- Read direction and procedure of the experiments very carefully.
- Always take precautions in handling measurements of voltage and current.

F. PROCEDURES

Part 1 : Temperature Effect on Single Connection of Solar Cell

1. Attach the wire or two electrical leads with an alligator clip to a solar cell and connect the red probe of the multimeter with the positive terminal of the solar cell while the black probe of multimeter will connect to the negative terminal of the solar cell as in Figure 2.3.
2. Record the readings of voltage and current in solar cells at room temperature in Table 2.1.
3. Expose the solar cell to direct sunlight for 30 seconds.
4. Record the readings of voltage and current in Table 2.1.
5. Repeat steps 2-3 to heat the solar cell for 1 minute and 2 minutes.

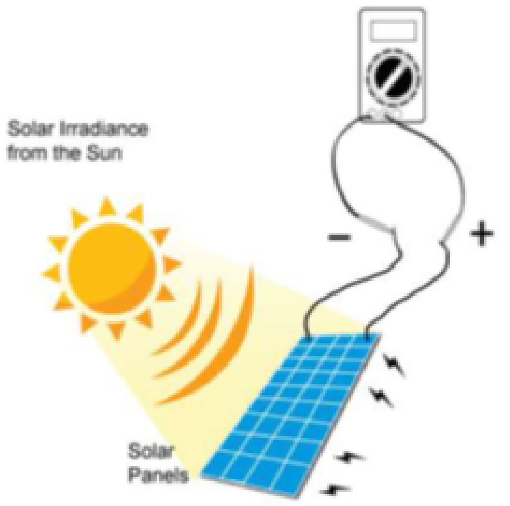


Figure 2.3 : Solar panel diagram exposed to sun / light source. [1]

Part 2 : Shading Effect on Parallel Connection of Solar Cell

1. Take 2 units of 6V solar cell with a size of 11cm x 6cm.
2. Attach the wire or two electrical lead with an alligator clip to a solar cell as Figure 2.4.
3. Joined the –ve terminal of solar cell A with the +ve terminal of solar cell B and -ve terminal of solar cell A with -ve terminal of solar cell B as in Figure 2.4.
4. Connect the -ve terminal to the black lead of the multimeter. Similarly, connect the +ve terminal to the red lead of the multimeter as shown in Figure 2.4.

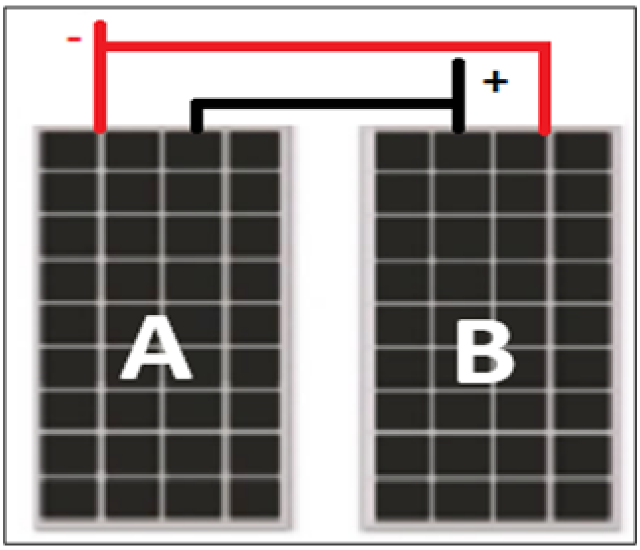


Figure 2.4 : Parallel connection of solar cell

5. Expose the solar cell directly under the sun or shine a light source as Figure 2.3.
6. Record the voltage and current readings in Table 2.2.
7. Keeping the sunlight constant (or the light source at a constant distance), shade half of one solar cell with a piece of cardboard or thick paper.
8. Record the voltage and current readings of the solar cell in Table 2.2.
9. Repeat steps 7-8 with the shaded area of one solar cell.

G. RESULT

Table 2.1: Effect of temperature on single connection solar cells (11cm x 6cm).
(DP1, DP3, DP4)

TEMPERATURE	**SINGLE CONNECTION**	
	CURRENT (mA)	**VOLTAGE (V)**
Room Temperature		
After 30 second		
After 1 minute		
After 2 minutes		

Table 2.2: Effect of shading on parallel solar cells (11cm x 6cm). (DP1, DP3, DP4)

SHADED AREA CONDITION	PARALLEL CONNECTION	
	CURRENT (mA)	VOLTAGE (V)
No Shade		
Half of One Solar Cell Covered		
Entire One Solar Cell Covered		

Practical Work 3

DEMONSTRATE OUTPUT POWER AND WIND SPEED OF A WIND TURBINE USING MATLAB SIMULATOR

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PRACTICAL WORK 3 : DEMONSTRATE OUTPUT POWER AND WIND SPEED OF A WIND TURBINE USING MATLAB SIMULATOR

CLO 2	Measure input and output parameters of renewable energy system using appropriate tools and equipment. (P4)	**PLO 5**	

A. OBJECTIVES

i. Investigate the effect of speed and blade design to the output power.
ii. Relate output power and wind speed of a wind turbine generator.

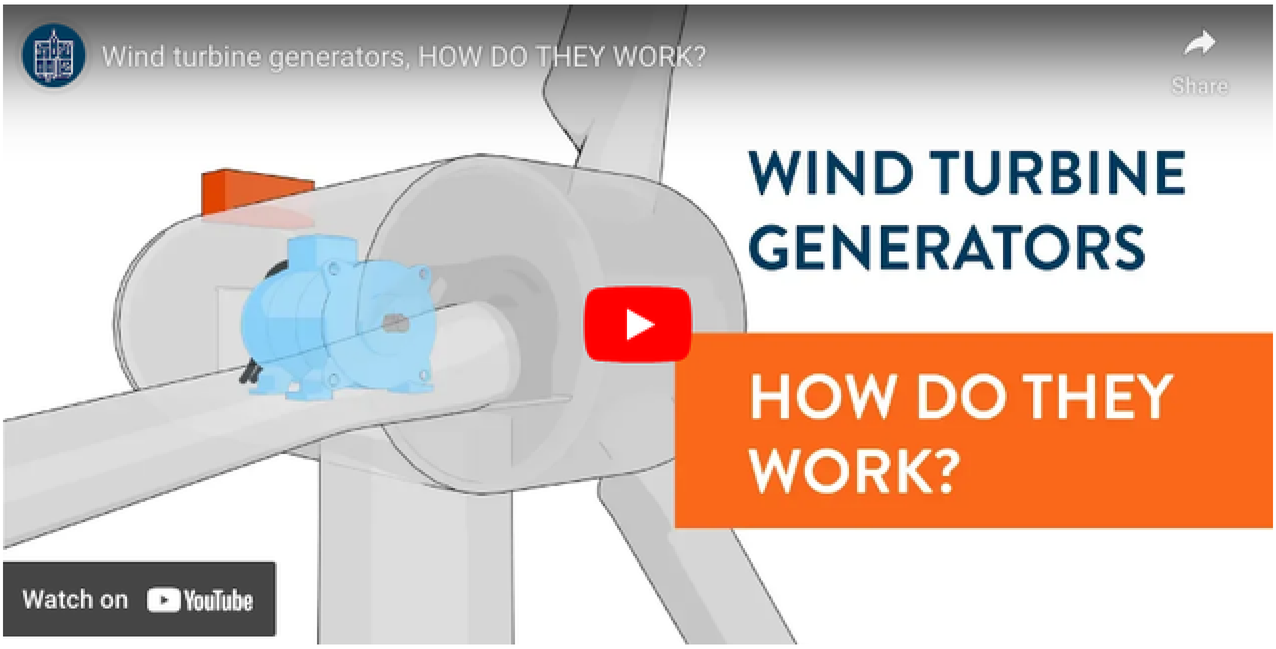
B. LEARNING OUTCOME

Analyze and interpret the relationship between wind speed and output power of a wind turbine using MATLAB simulator.

C. THEORY

Power has been extracted from the wind over hundreds of years with historic designs, known as windmills, constructed from wood, cloth and stone for the purpose of pumping water or grinding corn. Historic designs, typically large, heavy and inefficient, were replaced in the 19th century by fossil fuel engines and the implementation of a nationally distributed power network. A greater understanding of aerodynamics and advances in materials, particularly polymers, has led to the return of wind energy extraction in the latter half of the 20th century. Wind power devices are now used to produce electricity, and commonly termed wind turbines.

The device which converts the wind power into electricity is called wind turbine. This machine converts wind's kinetic energy into mechanical energy which is then converted into electrical energy as shown in Figure 3.1. In fact, the blades of the horizontal axis wind turbines are rotated through the wind. The conversion process uses the basic aerodynamic lift force to produce a net torque on the rotor shaft. The torque leads to a rotation of the shaft. The mechanical power produced on the shaft is finally converted into electrical energy through a generator.



Source : YouTube DOB-Academy

Figure 3.1 : Wind turbine generator

D. MATERIAL / TOOLS

- Computer
- MATLAB Simulink Software

E. SAFETY PRECAUTION

- Wear suitable PPE where required.
- Identify location of Fire Exit, Fire Extinguisher, First Aid Kit box and HIRARC sheets.
- Avoid unsafe activities during practical work.
- Carefully follow the lecturers' instructions to avoid personal injury and damage to the equipment.
- Check the hand tools and equipment in good working condition.
- Verify electrical power supply connection before powering up. Seek advice from lecturer when necessary or if the practical work procedures require you to do so.
- Never remove any component when the power is on.
- Read direction and procedure of the experiments very carefully.
- Always take precautions in handling measurements of voltage and current.

F. PROCEDURES

1. Double click on MATLAB.exe to start the simulation.
2. Click Open > File Name (Wind Turbine Blade) > Run.
3. Fig. 3.2 shows the MATLAB simulator for the wind turbine model.
4. Set the number of blades to 3 blades.
5. Change the blade length and wind speed according to Table 3.1-3.4.
6. Record the turbine power obtained from the simulation.

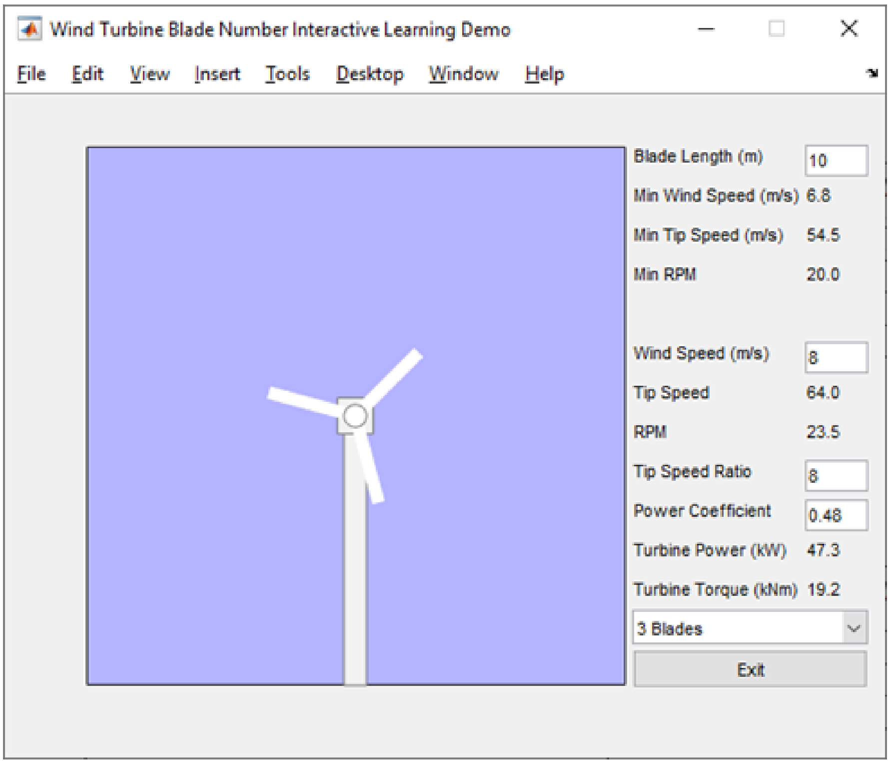


Figure3.2 : Wind turbine simulator model

G. RESULT

Table 3.1 : Output for blade length, 10 m

BLADE LENGTH = 10 m	
Wind Speed (m/s)	**Turbine Power (kW)**
8	
10	
12	
14	
16	

Table 3.2 : Output for blade length, 15 m

BLADE LENGTH = 15 m	
Wind Speed (m/s)	**Turbine Power (kW)**
8	
10	
12	
14	
16	

Table 3.3 : Output for blade length, 20 m

BLADE LENGTH = 20 m	
Wind Speed (m/s)	**Turbine Power (kW)**
8	
10	
12	
14	
16	

Table 3.4 : Output for blade length, 25 m

BLADE LENGTH = 25 m	
Wind Speed (m/s)	**Turbine Power (kW)**
8	
10	
12	
14	
16	

Practical Work 4

DESIGN AND ANALYSIS OUTPUT OF WIND TURBINE PERFORMANCE

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PRACTICAL WORK 4 : DESIGN AND ANALYSIS OUTPUT OF WIND TURBINE PERFORMANCE

CLO 2	Measure input and output parameters of renewable energy system using appropriate tools and equipment. (P4)	**PLO 5**	**DP1, DP3, DP4**
CLO 3	Demonstrate understanding of environmental & sustainability practices in renewable energy field through a given task session. (A3)	**PLO 7**	

A. OBJECTIVES

i. Design and build the wind turbine model using recyclable materials.
ii. Demonstrate and investigate the output current and voltage of wind turbine performance.
iii. Investigate output current and voltage with respect to variation wind speed of wind turbine performance.

B. LEARNING OUTCOME

Develop the prototype of a wind turbine and conduct the performance measurements (voltage, current) of wind turbine turbine prototype under variation of blade length and locations.

C. THEORY

The depletion of the world's fossil fuel supplies poses a significant threat to the long-term sustainability of the global economy. Wind energy emerges as a viable alternative that not only offers flexibility but also contributes to environmental preservation and national energy security. Historically, wind power has been utilized for various purposes such as powering sails, windmills, and wind pumps. However, in contemporary times, the primary application of wind energy is the generation of electricity through the use of wind turbines.

A wind turbine functions by harnessing the kinetic energy of the wind to generate electricity, thereby producing wind energy. The blades of a rotor-mounted turbine are driven by the force of the wind, which in turn rotates the generator to create electricity. There are two main types of wind turbines: horizontal-axis wind turbines (HAWTs) and vertical-axis wind turbines (VAWTs). HAWTs, which are more commonly used, feature two or three long, slender blades that are designed to directly face the wind for optimal efficiency. On the other hand, VAWTs have a distinct design with shorter, broader, curved blades that are symmetrical in shape. While both types of wind turbines serve the same purpose of generating electricity from wind energy, they differ in their blade design and orientation to the wind.

The purpose of this experiment, the students must able to develop the wind turbine prototype and measure the power performance from the prototype.

Source : YouTube WindSunWisdom

Figure 4.1: Comparison of Horizontal Axis and Vertical Axis Wind Turbine

D. MATERIAL / TOOLS

- Wind Turbine Model
- DC Motor
- Multimeter

E. SAFETY PRECAUTION

- Wear suitable PPE where required.
- Identify location of Fire Exit, Fire Extinguisher, First Aid Kit box and HIRARC sheets.
- Avoid unsafe activities during practical work.
- Carefully follow the lecturers' instructions to avoid personal injury and damage to the equipment.
- Check the hand tools and equipment in good working condition.
- Verify electrical power supply connection before powering up. Seek advice from lecturer when necessary or if the practical work procedures require you to do so.
- Never remove any component when the power is on.
- Read direction and procedure of the experiments very carefully.
- Always take precautions in handling measurements of voltage and current.

F. PROCEDURES

Part 1 : Designing Wind Turbine Model

1. Student need to select the wind turbine to be designed and identify the feature of chosen type of wind turbine such as type of material, height and etc.. Example of wind turbine design as shown in Figure 4.2.

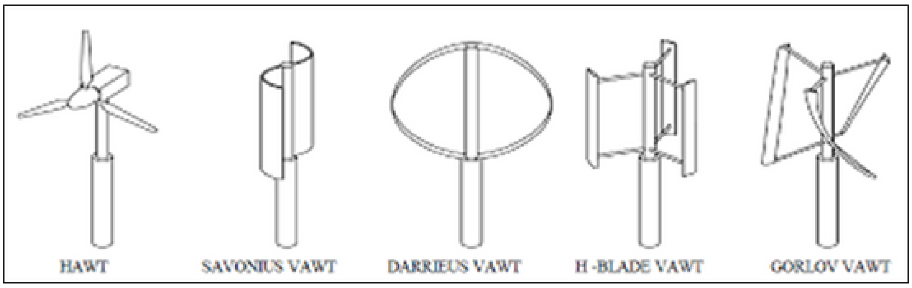

Figure 4.2 : Types of wind turbine

2. Build a wind turbine model using a recyclable material such as paper, popsicle stick, cardboard or etc.
3. Student need to design a wind turbine blade with two different blade lengths which are 8cm and 16cm that can be assembled and disassembled for this experiment.

Part 2 : Demonstrate and Measure Current Voltage of Wind Turbine Model

1. Prepare wind turbine model for demonstration.
2. Connect wind turbine model with blade sizing 8 cm to DC motor as shown in Figure 4.3.

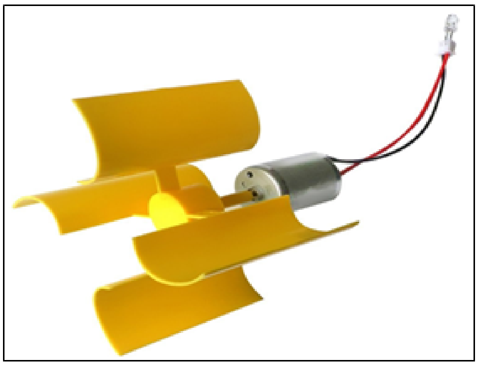

Figure 4.3 : Connection of wind turbine with a DC motor

3. Attach the red wire from the DC motor to the red lead of the multimeter.
4. Similarly, attach the black wires from the DC motor to the black lead of multimeter.
5. At Platform, place the wind turbine model directed to wind. Record current and voltage reading in Table 4.1.
6. Repeat step 2-5 with blade length 16cm. Record current and voltage reading in Table 4.1.
7. Repeat step 2-6 with location at Jetty and record the reading in Table 4.1.

G. RESULT

Table 4.1 : Current and Voltage of Wind Turbine Performance

Blade Length (cm)	Platform		Jetty	
	Voltage (V)	Current (mA)	Voltage (V)	Current (mA)
8				
16				

Practical Work 5

POWER PERFORMANCE ANALYSIS FOR MICRO HYDROELECTRIC WITH VARIABLE GROSS HEAD AND WATER FLOW RATE

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PRACTICAL WORK 5 : POWER PERFORMANCE ANALYSIS FOR MICRO HYDROELECTRIC WITH VARIABLE GROSS HEAD AND WATER FLOW RATE

CLO 2	Measure input and output parameters of renewable energy system using appropriate tools and equipment. (P4)	**PLO 5**	**DP1, DP3, DP4**

A. OBJECTIVES

i. Investigate the turbine power with water flow rate at different values of gross head effect.
ii. Investigate the turbine power with gross head at different values of water flow rate effect.
iii. Investigate power performance with respect to variation of water flow rate and gross head.

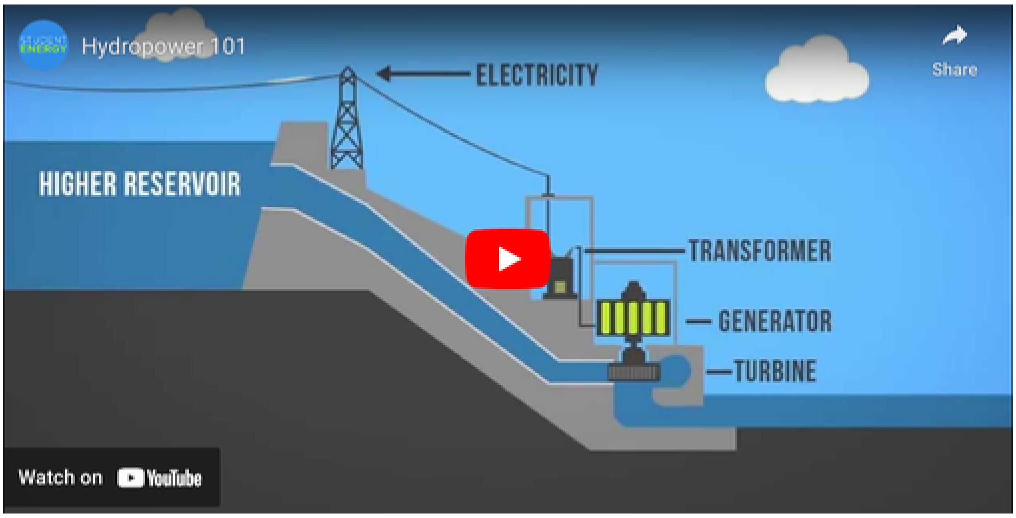
B. LEARNING OUTCOME

Conduct the turbine power performance measurements for a micro hydroelectric simulation model by utilizing MATLAB software, taking into account varying gross head and water flow rate parameters.

C. THEORY

Micro-hydropower is a dependable and efficient source of clean, sustainable energy. The process of generating electricity from water involves harnessing the kinetic energy produced by the motion of water. This is achieved as the potential energy of falling water is converted into kinetic energy, which then turns the blades of a hydraulic turbine. The turbine, in turn, rotates the generator rotor, transforming the mechanical energy into electrical energy. This entire system is known as a hydroelectric power plant. When designing a hydroelectric system, it is essential to consider two key factors: head and water flow.

Maximizing the potential of micro-hydropower plants requires careful planning and design. Identifying suitable locations and implementing appropriate power generation systems are crucial steps in this process. Additionally, the selection of turbine types and generator capacity, as well as the determination of water flow rate, play a significant role in the design of small hydropower plants. The flow rate, which refers to the volume of water diverted to flow over a turbine generator, directly impacts the amount of energy that can be converted into electricity. Furthermore, the head, which is the difference in water level between the inlet and outlet points, is an important factor to consider. The head determines the vertical height and is categorized into low, medium, and high heads based on their height, with higher heads allowing for a higher water flow rate to produce a given amount of electricity.



Source : YouTube Student Energy

Figure 5.1: Basic concept of micro hydroelectric power plant

The purpose of this experiment, the students must able to investigate and interpret the turbine power performance with respect to variation of water flow rate and gross head using MATLAB software.

D. MATERIAL / TOOLS

- Computer
- MATLAB Software

E. SAFETY PRECAUTION

- Wear suitable PPE where required.
- Identify location of Fire Exit, Fire Extinguisher, First Aid Kit box and HIRARC sheets.
- Avoid unsafe activities during practical work.
- Carefully follow the lecturers' instructions to avoid personal injury and damage to the equipment.
- Check the hand tools and equipment in good working condition.
- Verify electrical power supply connection before powering up. Seek advice from lecturer when necessary or if the practical work procedures require you to do so.
- Never remove any component when the power is on.
- Read direction and procedure of the experiments very carefully.
- Always take precautions in handling measurements of voltage and current.

F. PROCEDURES

Part 1 : Power Performance with Water Flow Rate at Different Values of Gross Head Effect

1. Double click on MATLAB.exe to start the simulation.
2. Click Open > File Name (Hydroelectric_PW5) >Run.
3. Double click the box of water flow rate 1.and gross head to set the values 2 m^3/s and 2m as shown in Figure 5.2 below.

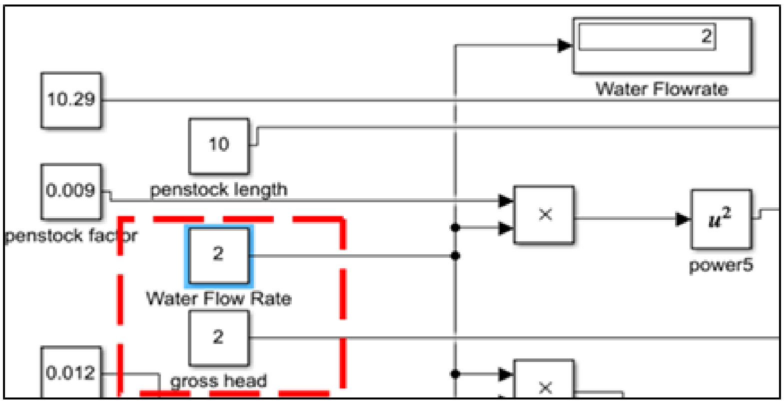


Figure 5.2 : Water flow rate and gross head setting [3]

4. Click Run.
5. Record the reading of Turbine Power, P (kW) as shown in Figure 5.3 in Table 5.1 and Table 5.2 in result section.

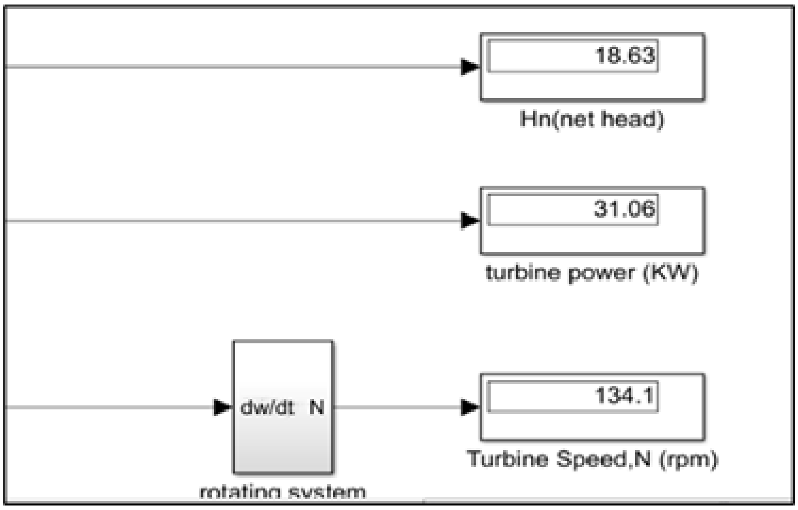


Figure 5.3: Turbine Power, P reading [3]

6. Repeat step 3-5 by vary values of water flow rate to 4 m^3/s, 6 m^3/s, 8 m^3/s, and 10 m^3/s.
7. Then, repeat step 3-6 by vary values of gross head to 4m, 6m, 8m, 10m.

Part 2 : Power Performance with Gross Head at Different Values of Water Flow Rate Effect.

1. Double click on MATLAB.exe to start the simulation.
2. Click Open > File Name (Hydroelectric_PW5) > Run.
3. Double click the box of water flow rate and gross head to set the values 0.2 m3/s and 20m as shown in Figure 5.4.

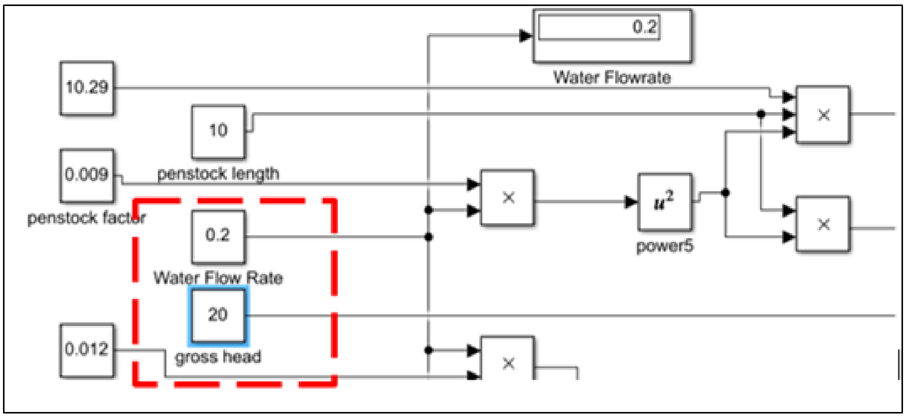


Figure 5.4 : Water flow rate and gross head setting [3]

4. Click Run.
5. Record the reading of Turbine Power, P (kW) as shown in Figure 5.5 in Table 5.2 in result section.

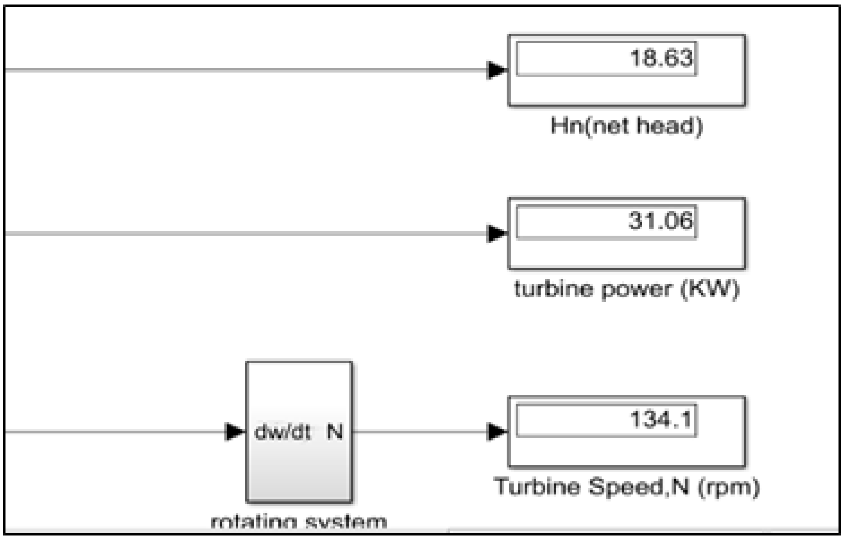


Figure 5.5: Turbine Power, P reading [3]

6. Repeat step 3-5 by vary the values of gross head 40m, 60m, 80m, and 100m.
7. Then, repeat step 3-6 by vary the values of water flow rate 0.4 m^3/s, 0.6 m^3/s, 0.8 m^3/s, and 1.0 m^3/s.

G. RESULT

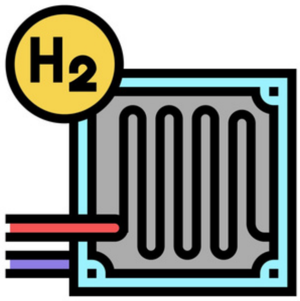
Table 5.1: Variation of turbine power with water flow rate at different values of gross head

Gross Head, Hg (m) / Water Flow Rate Q (m^3/s)	Turbine Power, P (KW)				
	2	**4**	**6**	8	**10**
2					
4					
6					
8					
10					

Table 5.2: Variation of turbine power with gross head at different values of water flow rate

Water Flow Rate, Q (m^3/s) / Gross Head, Hg (m)	Turbine Power, P (KW)				
	0.2	0.4	0.6	0.8	1.0
20					
40					
60					
80					
100					

Practical Work 6



DEMONSTRATE CHARACTERISTIC CURVE OF A FUEL CELL USING MATLAB SIMULINK

POLITEKNIK MALAYSIA
KUCHING SARAWAK

DEG30013 FUNDAMENTAL OF RENEWABLE ENERGY

PRACTICAL WORK 6 : DEMONSTRATE CHARACTERISTIC CURVE OF A FUEL CELL USING MATLAB SIMULINK

CLO 2	Measure input and output parameters of renewable energy system using appropriate tools and equipment. (P4)	**PLO 5**	

A. OBJECTIVES

i. Relate current of a fuel cell in electricity generation.
ii. Relate voltage of a fuel cell in electricity generation.
iii. Discuss the performance of PEMFC and SOFC of a fuel cell in electricity generation.

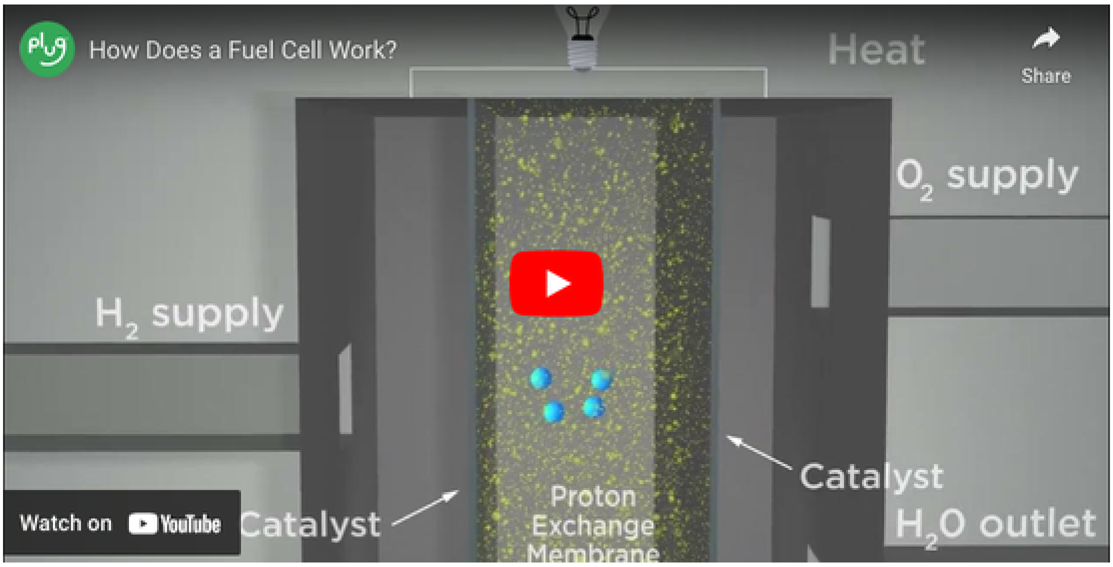
B. LEARNING OUTCOME

Conduct performance measurements for fuel cell simulation model by utilizing MATLAB software.

C. THEORY

A fuel cell is a device that generates electricity by a chemical reaction. The fuel cell enables hydrogen and oxygen fuel to be converted to electricity. A fuel cell is in principle a battery where the active elements are not solids (such as the lead in car battery) or liquids but gaseous. The principle of operation of the fuel cell is similar to electrolysis but in reverse; gases such as hydrogen and oxygen (or air) are pumped in and produce DC output. The only by products are water and there are virtually no pollutants. There is some heat, but much less than in most combustion-based generation systems, and there are no moving parts.

Every fuel cell has two electrodes called, respectively, the anode and cathode as shown in Figure 6.1. The reactions that produce electricity take place at the electrodes. Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes. Hydrogen is the basic fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution–much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless by product, namely water.



Source : YouTube Plug Power

Figure 6.1: Basic Principle of Fuel Cell

The purpose of this experiment, the students must able to investigate and interpret the power performance of PEMFC and SOFC using MATLAB software.

D. MATERIAL / TOOLS

- Computer
- MATLAB Simulink Software

E. SAFETY PRECAUTION

- Wear suitable PPE where required.
- Identify location of Fire Exit, Fire Extinguisher, First Aid Kit box and HIRARC sheets.
- Avoid unsafe activities during practical work.
- Carefully follow the lecturers' instructions to avoid personal injury and damage to the equipment.
- Check the hand tools and equipment in good working condition.
- Verify electrical power supply connection before powering up. Seek advice from lecturer when necessary or if the practical work procedures require you to do so.
- Never remove any component when the power is on.
- Read direction and procedure of the experiments very carefully.
- Always take precautions in handling measurements of voltage and current.

F. PROCEDURES

1. Double click on MATLAB.exe to start the simulation.
2. Click Simulink > Open > FUEL_CELL.slx > Log Selected Signals > Run > Simulation Data Inspector.
3. Figure 6.2 shows the MATLAB Simulink of fuel cell model.

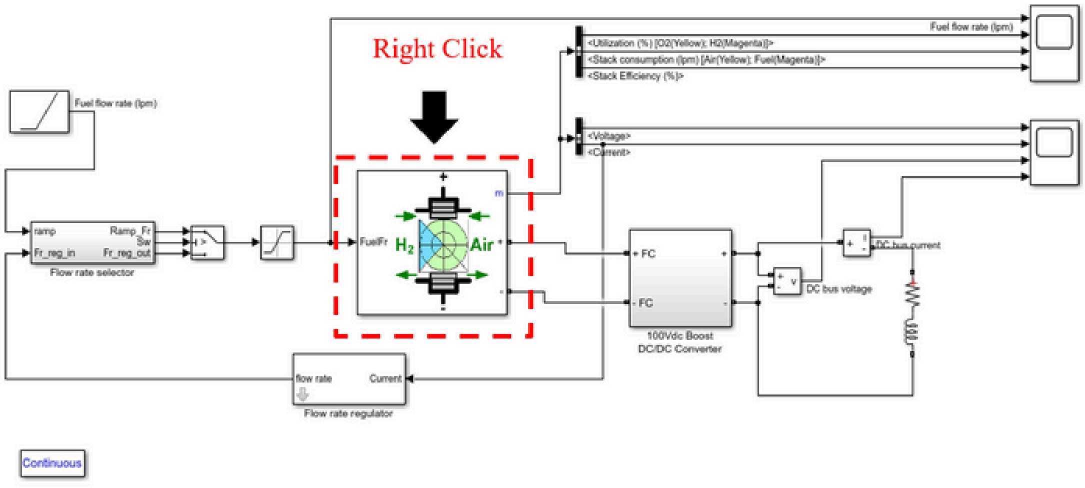


Figure 6.2 : MATLAB Simulink – fuel cell model[4]

4. Right click fuel stack indicated in red box and click Properties.
5. Figure 6.3 shows the fuel cell stack properties.

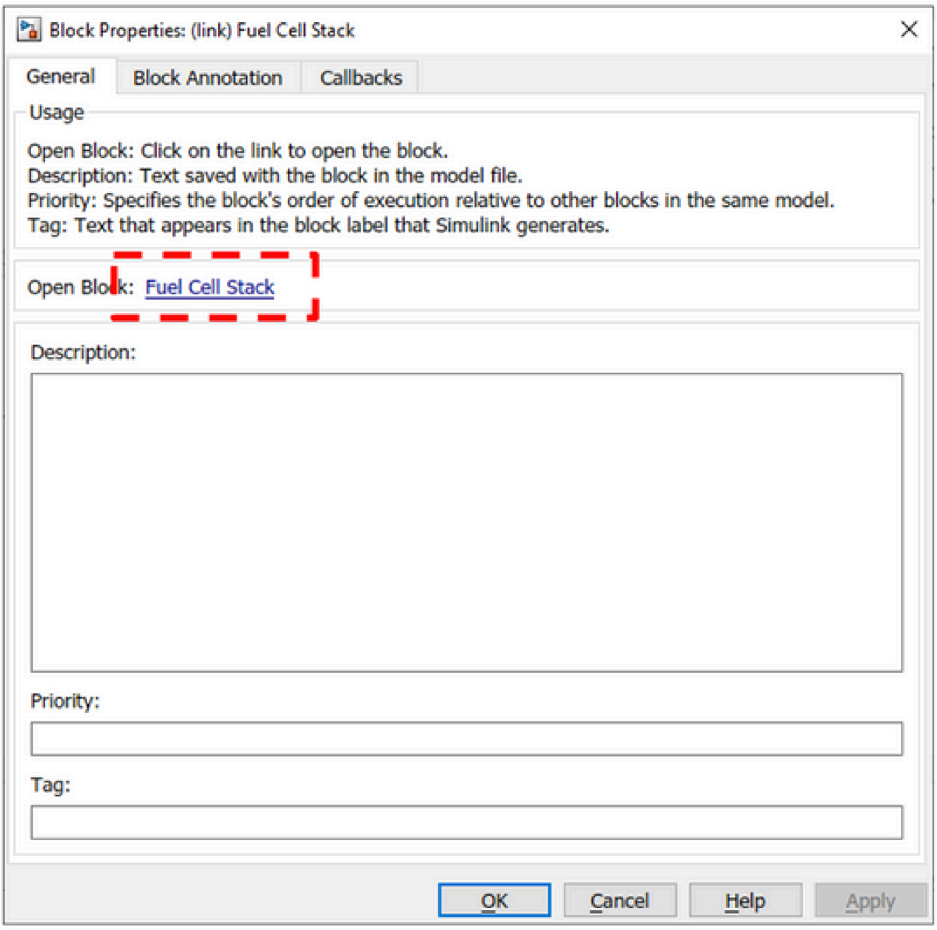


Figure 6.3 : Block Properties of Fuel Cell Stack[4]

6. Click Fuel Cell Stack as indicated in red box in Figure 6.3.
7. Set the preset model to PEMFC – 6 kW – 45 Vdc and click apply.
8. Click Plot V_I characteristic as indicated in red box in Figure 6.4 to obtain fuel cell curves.

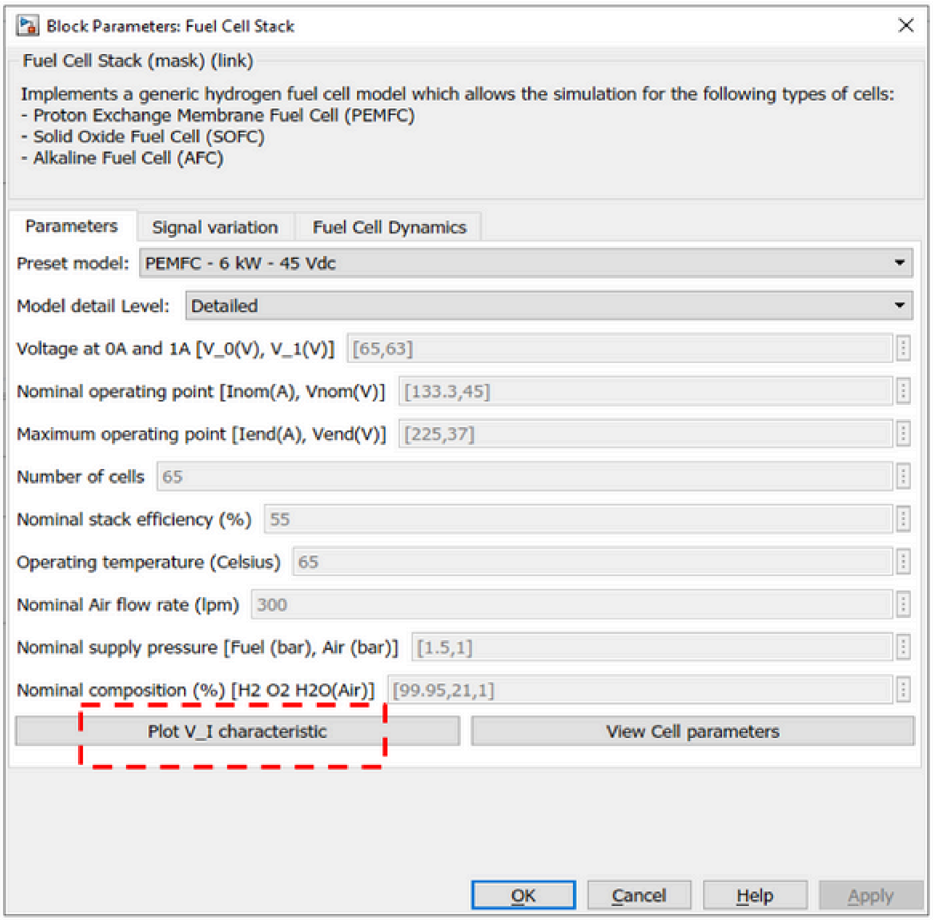


Figure 6.4: Block parameters of fuel cell stack[4]

9. Copy the figure obtained for fuel cell simulation.
10. Repeat step 1-9 by changing the preset model to SOFC – 3 kW – 100 Vdc.

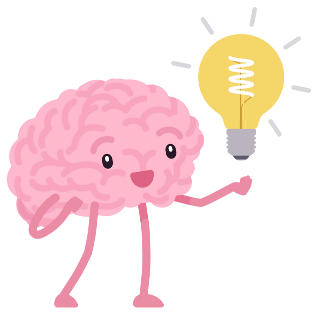
G. RESULT

In your report, include the following results of:

i. Stack power vs current of both fuel cell.

ii. Stack voltage vs current of both fuel cell.

Brain Test




QUIZ
TIME!!

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POLITEKNIK MALAYSIA KUCHING SARAWAK

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